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PNGS 'A' LIQUID ZONE CONTROL UNIT VIBRATION MONITORING

Report No 87-5-K

H.L. Anderson, Engineer
Plant Equipment Dynamics Section
Mechanical Research Department

ABSTRACT

Pickering NGS 'A' requested that vibration monitoring of a liquid zone control unit (LZCU) be performed in Unit 3 to determine if vibration levels were severe enough to warrant inspection of the LZCU's in Units 1 or 2. On-line vibration of LZCU #2 in Unit 3 was performed.

The results of the monitoring program are documented in the report. Recommendations for further evaluation of the zone control unit vibration are made based upon a need for a long term analysis of the vibration of structures in the calandria.

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EXECUTIVE SUMMARY

PNGS 'A' LIQUID ZONE CONTROL UNIT VIBRATION MONITORING

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Vibration monitoring was performed on liquid zone control unit (LZCU) number 2 in Unit 3 to assess the vibration levels and determine the need to inspect the LZCU's in Units 1 and 2 while they are shut down for pressure tube replacement.

The monitoring request was a consequence of the failure of a liquid zone control unit at Bruce A where fretting around the calandria-nozzle/bearing area led to formation of a hole in the outer wall of the LZCU. Vibration monitoring at Bruce revealed that the fretting was caused by flow-induced excitation of the LZCU's that were in the jet flow from the moderator inlet nozzles. The PNGS 'A' moderator distribution is symmetrical and would not cause the same problems encountered at BNGS 'A'; however, the large bearing clearances at Pickering warranted the assessment of the vibration levels following several years of operation.

The monitoring was performed on the top of LZCU 2. Deck motion was monitored simultaneously to determine the dependence of LZCU vibration on deck motion. The monitoring was performed over a six month period under transient and steady-state operating conditions.

The following conclusions and recommendations have arisen from the results of the monitoring:

1) The rms vibration levels measured on the zone control unit under the operating conditions tested were approximately 2 μm rms. The maximum instantaneous vibration level measured on the LZCU under normal operating conditions was 16.4 μm p-p in the N-S direction.

2) Under normal operating conditions the LZCU motion was independent of the deck motion. The dominant LZCU frequency of vibration was 16.6 Hz in both the N-S and E-W directions.

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3) The vibration levels at Pickering were at least 50% lower than those at Bruce under normal operating conditions; however, comparison of absolute levels between Bruce and Pickering is not strictly valid. Based on the data gathered in this six month survey, there is no evidence to support an inspection of a zone control unit.

4) It is recommended that the data obtained in this study be viewed as baseline vibration data to be used for comparison with data obtained periodically over the ensuing years. The instrumentation is in place on the LZCU and monitoring should be performed at regular intervals of approximately 6 months to track the behaviour of the LZCU with time.

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To Mr. K. Talbot
Manager, Commissioning Section
Pickering NGS 'A'

PNGS 'A' LIQUID ZONE CONTROL UNIT VIPRATION MONITORING

1.0 INTRODUCTION

Pickering NGS requested that vibration monitoring be performed on a liquid zone control unit (LZCU) on-line in Unit 3 to assess the vibration levels and determine the need to inspect the LZCU's in units 1 and 2.

The monitoring request was a consequence of the failure of a liquid zone control unit at Bruce 'A' where fretting around the calandria nozzle/bearing area led to formation of a hole in the outer wall of the LZCU. Vibration monitoring/1/ at Bruce on the LZCU's revealed that the fretting was caused by flow-induced excitation of LZCU's 1 and 3 that were in the jet flow from the moderator inlet nozzles.

The moderator flow distribution at PNGS 'A' is symmetrical and would not pose the same problems encountered at BNGS 'A'. However, the PNGS 'A' bearing clearances (4 mm radial) warranted the assessment of the vibration levels following several years of operation.

The general arrangement of the LZCU's in the calandria is shown in a plan view in Figure 1. A detailed view of a zone control unit is presented in Figure 2.

LZCU 2 was selected for monitoring because of its relative ease of access. The deck motion was also monitored following the experience at Bruce NGS 'A' which indicated that some of the LZCU motion was due to that of the deck/shield structure. The vibration monitoring was performed at several transient and steady-state conditions. The instrumentation was left in place at the completion of the test program.

The results of the monitoring, with recommendations for further work, are presented in the report.

2.0 INSTRUMENTATION AND MONITORING PROCEDURE

The greatest obstacle to be overcome in the project was the routing of the instrumentation wiring from the LZCU out of containment to the vibration room. No spare instrumentation lines were available in Unit 3. After a great deal of discussion the decision was made to use some of the phase marker lines from the Pump Monitoring System. To keep the number of lines used to a minimum, only the one LZCU and the deck were instrumented. The instrumentation set-up for the work is depicted in Figure 3.

2.1 LZCU Instrumentation

The accelerometers used to monitor LZCU motion were mounted in an aluminum disk which was placed on the top of the zone control unit. Tests on a Bruce 'B' LZCU during construction/1/ demonstrated that the motion at the top of the LZCU and that at the calandria nozzle were coherent although not of the same order of magnitude. The Bruce 'B' data were used to determine the validity of using the motion at the accessible top of the LZCU to monitor the severity of the motion at the inaccessible calandria nozzle LZCU bearing area. The results of the study on the Bruce 'A' LZCU's confirmed the procedure. The data from the top of the LZCU in the position of the failed unit demonstrated a trajectory of motion that matched exactly the wear pattern on the failed LZCU at the calandria nozzle location.

Two Endevco 5241 accelerometers were mounted orthogonally in the disk in the horizontal plane for monitoring LZCU motion in velocity and displacement. The E-W direction (ref Figure 1) was monitored by accelerometer #3 while the N-S direction was monitored by accelerometer #4. A B&K 4368 accelerometer, #5, was mounted on the top of the disk to monitor for impacting of the LZCU.

2.2 Deck Instrumentation

The deck motion was monitored by two Endevco 5241 accelerometers mounted orthogonally in the horizontal plane on a block which was magnetically fixed to the deck as shown in Figure 3. The accelerometers were aligned to match the orientation of the accelerometers on the LZCU: accelerometer #1 in the N-S direction; accelerometer #2 in the E-W direction.

2.3 Monitoring Conditions

The vibration of the LZCU and deck were monitored under the following operating conditions:

1. Moderator dump: - Primary heat transport (PHT) system in operation;
2. Unit outage: - PHT system out of service, Shutdown Cooling System (SDC) in operation;
3. 102.4% reactor power;
4. 75% reactor power, during start-up;
5. 103.2% reactor power;
6. 103.3% reactor power;
7. 103.1% reactor power;
8. 100% reactor power.

3.0 RESULTS AND DISCUSSION

3.1 Results

The data collected at the eight operating conditions have been summarized in Tables 1 through 3. The recorded signals were high-pass filtered at 2.0 Hz to reduce electronic overshoot effects introduced by the instrumentation.

The rms displacement data are documented in Table 1. These overall levels were calculated on the GENRAD Model 2510 Modal Analyzer using the ASP4CH FFT program.

Maximum peak-to-peak displacement data are listed in Table 2. These data represent the largest peak-to-peak displacement measured on the LZCU and deck for each direction at each condition; they are not necessarily simultaneous occurrences.

Frequency data in descending order of dominance are listed in Table 3. These data were generated using both the GENRAD system and the Nicolet 660B analyzer. Coherence and phase relationships between the LZCU and the deck data for both directions were also examined to determine the dependence of the zone control unit motion on the deck motion.

Examination of the displacement data in Tables 1 and 2 revealed that the highest LZCU displacements were measured under the shutdown conditions of PHT-off/SDC-on and moderator dump. The maximum LZCU displacements measured were 38 μm p-p, 5.78 μm rms, in the N-S direction and 24 μm p-p, 3.44 μm rms, in the E-W direction with the PHT-off/SDC-on. A trajectory plot of the LZCU motion under the PHT-off/SDC-on condition is shown in Figure 4. The trajectory demonstrates a slight predominance of motion in the N-S direction as was indicated in the overall level data.

Under the operating or start-up conditions tested the LZCU displacement remained relatively constant at 12-16 μm peak-peak, 2.0 μm rms, in the N-S direction and 10-15 μm peak-peak, 1.6 μm rms, in the E-W direction.

The maximum deck displacement occurred under the moderator dump condition. The measured maximum displacements were 8.4 μm peak-peak, 1.68 μm rms, in the N-S direction and 7.6 μm peak-peak, 1.66 μm rms in the E-W direction. The lowest deck displacements were measured under the PHT-off/SDC-on condition. Under operating conditions the deck displacements were relatively constant at approximately 4.5 μm peak-peak, 0.67 μm rms, in the N-S direction and 2.0 μm peak-peak, 0.36 μm rms, in the E-W direction.

The first three dominant frequencies from the displacement spectra from the LZCU and deck are listed in Table 3 for each condition tested. Commonality of dominant frequencies between the zone and deck is observed only during the two shutdown tests. During operation the dominant modes of vibration are at approximately 10 Hz for the deck N-S, 2 Hz for the deck E-W, and 16.6 Hz for the LZCU in both directions.

The coherence between the zone and the deck motion was low at the common resonant frequencies as shown in the PHT-off/SDC-on coherence spectra for corresponding directions in Figures 5a and 5b.

3.2 Discussion

The low coherence between the zone and deck motion even at the high excitation under the shutdown tests and the lack of common dominant frequencies under operation indicates that the LZCU motion is independent of the deck. This situation is markedly different from that at Bruce 'A' where the zone and deck motion were found to be coherent and in phase at the two lowest dominant frequencies. The different behaviour of the LZCU's at Pickering and Bruce may, in part, be explained by the clearances at the calandria nozzle at each station. At Bruce NGS the as-built clearances between the support pads on the LZCU and the calandria nozzle were 0.75 mm radial; without the pads the clearances would be 2.5 mm radial. Only on the LZCU's where the pads had worn off did the Bruce LZCU's exhibit motion at frequencies other than those of the deck and these were presumed to be due to the LZCU impacting on the

calandria. In the Pickering 'A' LZCU's the as-built clearance between the LZCU and the calandria nozzle was 4 mm radial or 5 times that at Bruce 'A'. Under the PNGS 'A' conditions it would require extremely large calandria/deck motions for the zone control units to be dragged along with the calandria, a situation where, as at Bruce, the small relative motions between the calandria nozzle and the LZCU would result in wear.

It is not possible to compare in absolute terms the vibration levels at Pickering to those measured at Bruce because of differences in the design of the respective zone control units, calandria structures and moderator flow distribution, all of which affect the vibration response. With the foregoing caveat in mind, the maximum instantaneous peak-to-peak vibration levels measured at Pickering under normal operating conditions were lower than those measured on the susceptible units at Bruce 'A' by approximately 50%; eg 32 µm peak-peak was measured on the long axis of the orbit at Bruce compared to 16 µm peak-peak on the long axis of the orbit at Pickering. The Pickering rms vibration levels were much lower, on the order of 2 µm rms compared to 10 µm rms at Bruce.

The severity of the vibration levels cannot be judged based on a data sample covering only a six month period. The long operating record at Pickering without a LZCU failure and the large clearances coupled with the low rms vibration levels would indicate that the situation at Pickering is not critical; certainly there is not sufficient evidence to support an inspection of a zone control unit at this time. In absolute terms the data obtained in this study can only be used as a baseline level and further monitoring should be performed at regular intervals to track the change in LZCU condition with time.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 The rms vibration levels measured on the zone control unit under the operating conditions tested were approximately 2 µm rms. The maximum instantaneous vibration level measured on the LZCU under normal operating conditions was 16.4 µm p-p in the N-S direction. The N-S direction motion was marginally dominant over the E-W direction.

4.2 Under normal operating conditions the LZCU motion was independent of the deck motion. The dominant LZCU frequency of vibration was 16.6 Hz in both the N-S and E-W directions.

4.3 The vibration levels at Pickering were at least 50% lower than those at Bruce under normal operating conditions; however, comparison of absolute levels between Bruce and Pickering is not strictly valid. Based on the data gathered in this six month survey, there is no evidence to support an inspection of a zone control unit.

4.4 It is recommended that the data obtained in this study be viewed as baseline vibration data to be used for comparison with data obtained periodically over the ensuing years. The instrumentation is in place on the LZCU and monitoring should be performed at regular intervals of approximately 6 months to track the behaviour of the LZCU with time.

Approved:

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REFERENCES

1. H.L. Anderson, "Bruce NGS 'A': Vibration Monitoring to Study Liquid Zone Control Unit Failure", Report 83-124-K, April, 1983.

Table 1: RMS Displacement Data

Condition	RMS Displacement in μm Deck N-S	Deck E-W	LZCU E-W	LZCU N-S
1. mod. dump	1.68	1.66	2.24	3.22
2. PHT off; SDC on	0.25	0.36	3.44	5.78
3. 102.4% R.P.	0.69	0.41	1.6	2.13
4. 75% R.P.	0.68	0.42	2.0	2.23
5. 103.2% R.P.	0.66	0.41	1.5	1.9
6. 103.3% R.P.	0.65	0.3	1.4	1.7
7. 103.1% R.P.	0.66	0.3	1.6	1.8
8. 100% R.P.	0.69	0.3	1.4	1.8

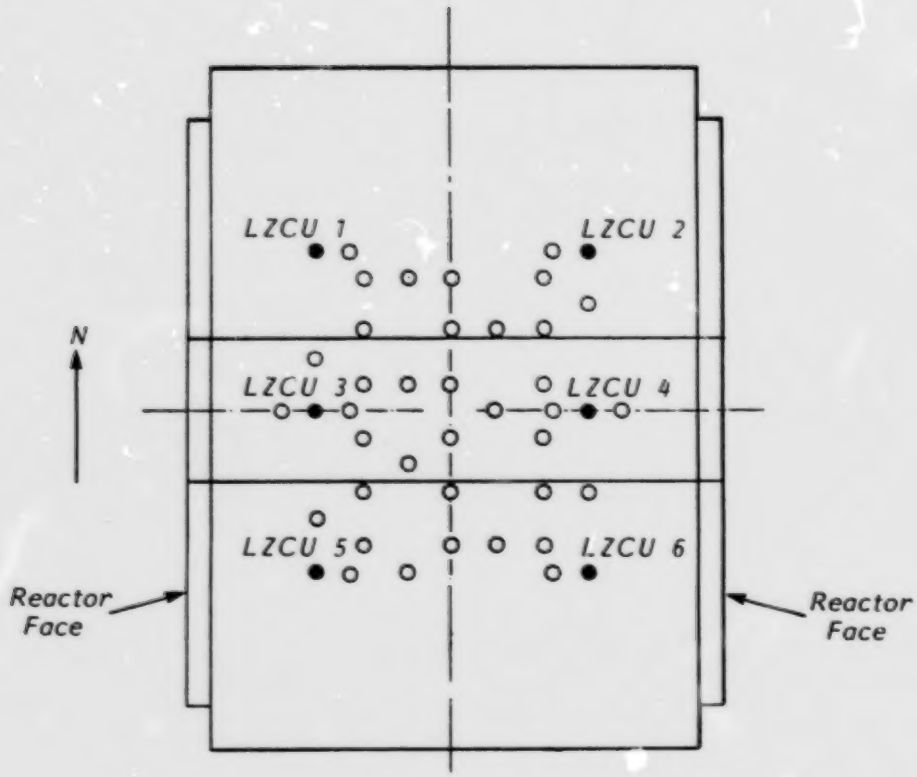
Table 2: Peak-to-Peak Displacement Data

	Peak -to-Peak Displacement in μm			
Condition	Deck N-S	Deck E-W	LZCU E-W	LZCU N-S
1. Mod. dump	8.4	7.6	13.3	18.96
2. PHT off; SDC on	1.8	1.0	24.0	38.0
3. 102.4% R.P.	4.8	2.0	11.4	15.2
4. 75% R.P.	4.8	1.6	15.2	16.4
5. 103.2%R.P.	4.0	2.2	11.4	12.6
6. 103.3% R.P.	4.0	1.9	10.7	12.6
7. 103.1%R.P.	4.2	2.0	12.0	13.3
8. 100% R.P.	4.8	2.4	10.1	12.0

Table 3: Frequency Data

Frequency in Hz in descending order of dominance

Condition	Deck N-S	Deck E-W	LZCU E-W	LZCU N-S
1. Mod. Dump	4.25, 3.4, 2.9	4.25, 3.4, 2.9	4.25, 2.9, 13.8	4.25, 16.3, 2.9
2. PHT off; SDC on	2.1, 4.0, 4.6	2.0, 2.9, 2.6	2.1, 2.9, 16.4	2.3, 16.3, 2.5
3. 102.4% R.P.	5.3, 9.9, 10.5	1.9, 2.3, 8.6	16.5, 13.9, 2.4	15.6, 16.0, 16.3
4. 75% R.P.	10.0, 5.1, 9.5	1.9, 2.4, 8.0	16.8, 10.0, 2.4	15.8, 16.6, 16.1
5. 103.2% R.P.	10.1, 5.3, 2.0	2.1, 8.1, 8.6	16.6, 2.5, 2.3	15.6, 13.9, 16.5
6. 103.3% R.P.	10.0, 10.3, 5.1	1.9, 8.4, 8.6	16.8, 2.4, 13.6	16.5, 15.5, 15.9
7. 103.1% R.P.	10.0, 5.0, 4.6	2.1, 8.3, 2.6	16.6, 17.5, 14.0	16.3, 15.8, 14.0
8. 100% R. P.	10.4, 4.8, 5.3	2.3, 8.1, 8.5	16.5, 16.8, 17.4	15.8, 16.3, 14.0



● Zone Control Units
○ Other Reactivity Control And Monitoring Units

FIGURE 1
REACTIVITY CONTROL UNIT ARRANGEMENT

173658-RD

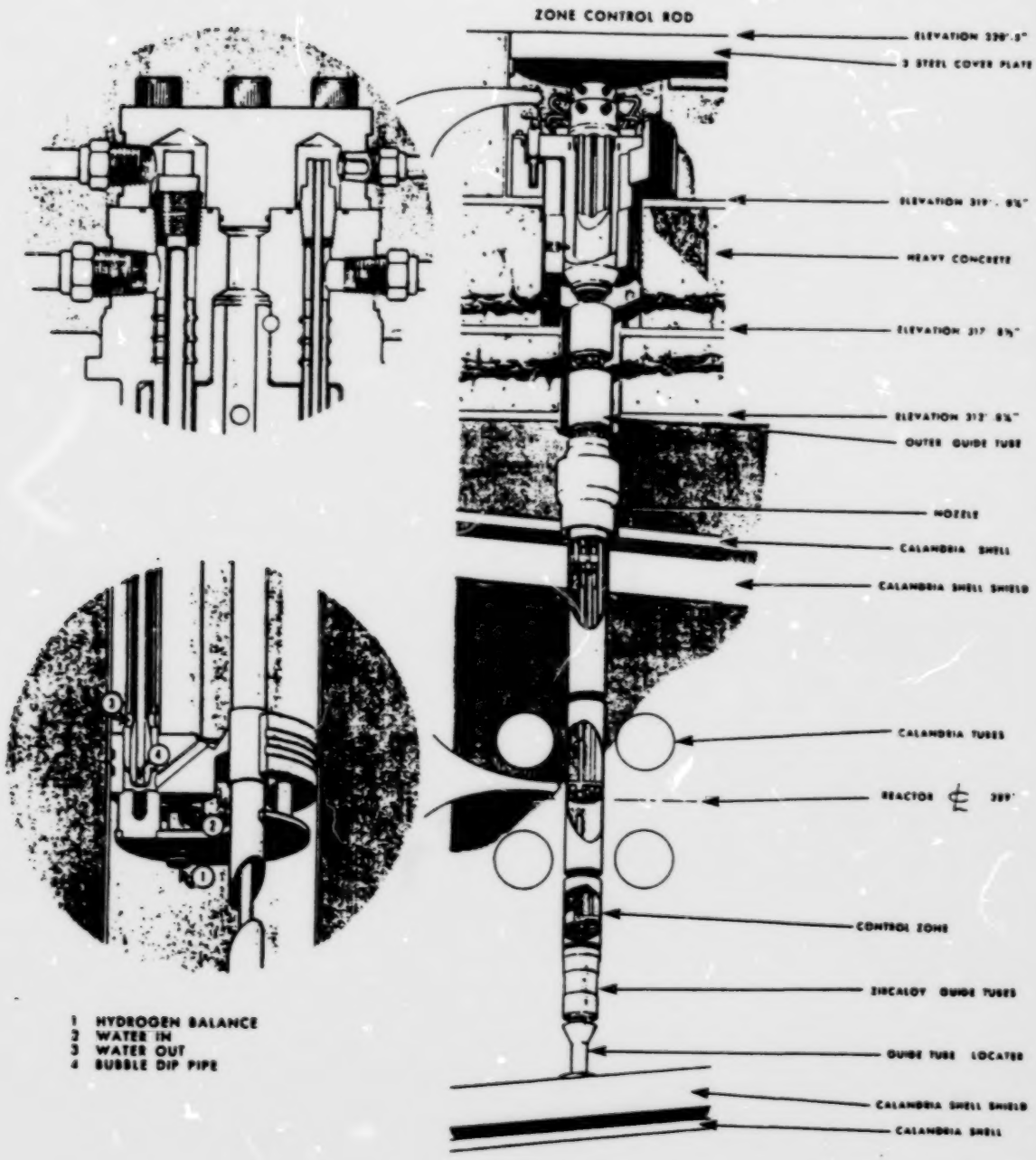


FIGURE 2

ELEVATION AND DETAIL VIEWS OF
A LIQUID ZONE CONTROL UNIT

173659-RD

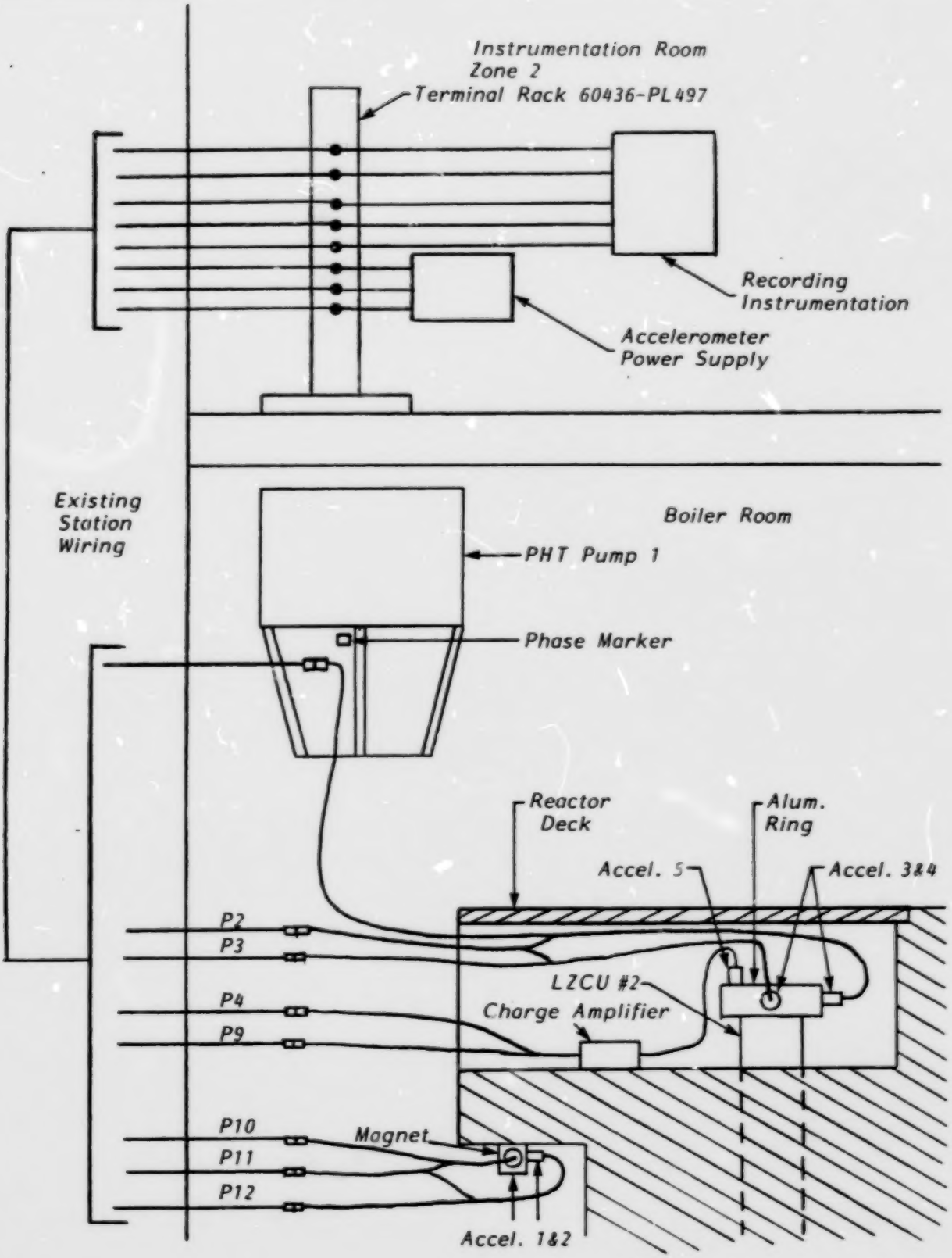


FIGURE 3
INSTRUMENTATION SET-UP

173660-RD

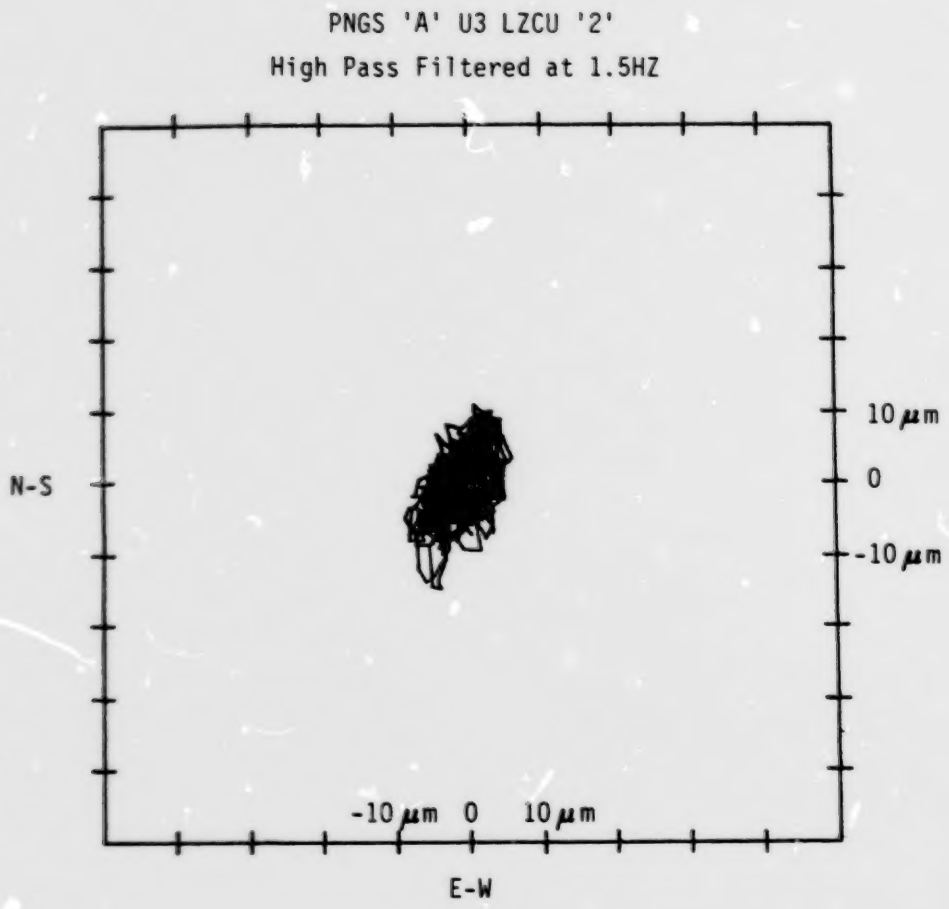


FIGURE 4
TRAJECTORY OF LZCU UNDER PHT-OFF/SDC ON CONDITIONS

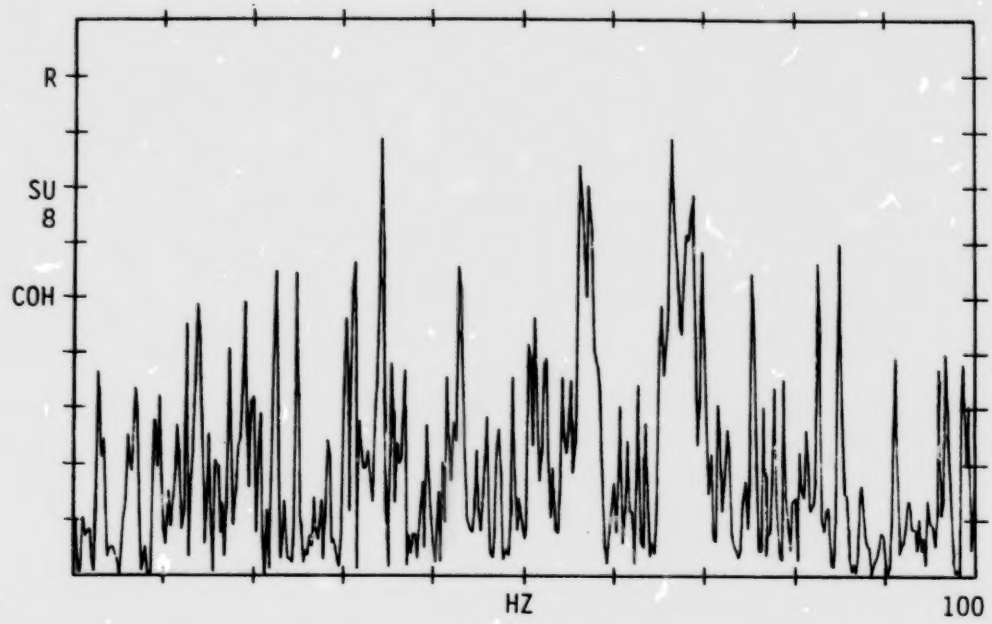


FIGURE 5a

COHERENCE BETWEEN DECK AND LZCU IN N-S DIRECTION
UNDER PHT OFF/SDC-ON CONDITIONS

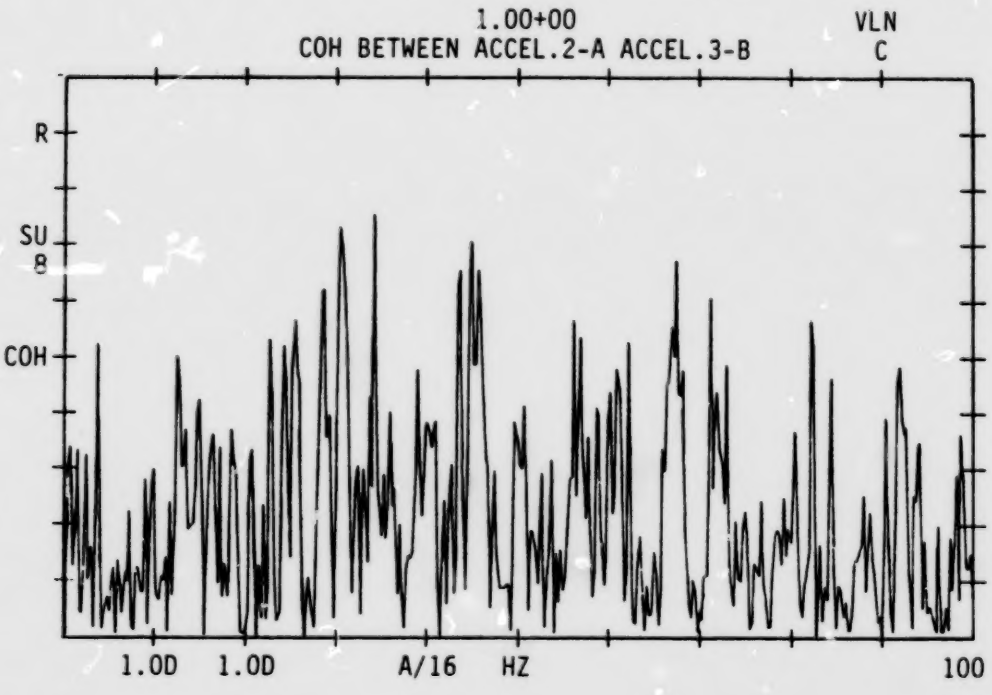


FIGURE 5b

COHERENCE BETWEEN DECK AND LZCU IN E-W DIRECTION
UNDER PHT OFF/SDC-ON CONDITIONS

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